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Successful Treatment of Severe Ulcerative Dermatitis in an Aubry's Flapshell Turtle (*Cycloderma aubryi*)

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Abstract

An adult, wild-caught, intact female Aubry's flapshell turtle (*Cycloderma aubryi*), that had been in the collection for 21 months, presented with rapid onset of multifocal, tan-white, 1.5 cm and smaller, crateriform, ulcerated lesions on the carapace and plastron. Empirical antibiotic therapy, initiated on the suspicion of an infectious etiology, yielded no clinical improvement and the disease progressed. Multifocal osteomyelitis was visible deep to the dermatological lesions on the carapace and plastron on computed tomography (CT) imaging, and culture results included *Stenotrophomonas maltophilia* and *Achromobacter* (*Alcaligenes*) *xylosoxidans*. Two months after surgical debridement and ostectomy, healing of lesions was incomplete and slow to progress. Photobiomodulation (PBM) was initiated on some of the lesions, and the treated lesions showed grossly visible indications of progressive healing after 17 days; there were no indications of healing in the untreated lesions. All lesions were subsequently treated with PBM, and the patient made a full recovery. This case report describes successful treatment of severe ulcerative dermatitis in a softshell turtle using advanced imaging (CT), surgical debridement and ostectomy, supportive care, husbandry modifications, and PBM. This report highlights that PBM can be a valuable therapeutic tool that should be considered for treatment of ulcerative dermatitis in softshell turtles, especially in patients with delayed wound healing or chronic dermatologic lesions.

Key Words: *Cycloderma aubryi*, laser therapy, photobiomodulation (PBM), shell rot, softshell turtle, ulcerative dermatitis

Introduction

Among extant turtles, softshells (Trionychidae) belong to the group that deviates the most from the general chelonian body plan. The bony shell is greatly reduced, and its flat bony elements have a unique surface sculpturing with internal and external compact layers, framing an inner cancellous core; the shell surface is covered by leathery skin rather than horny scutes (Fritz *et al*., 2011). Infection of the leathery skin can progress quickly and may invade the thin underlying bony structures and the coelomic cavity, with acute and peracute presentations reported (Frye *et al*., 1984; Murray *et al*., 2009; P. Praschag, personal observation). The extent of infection and necrosis beneath the bony shell can be difficult to identify, assess, and treat, especially in severe or advanced cases (Innis *et al*., 2022). Aubry's flapshell turtles (*Cycloderma aubryi*) are listed as Vulnerable (VU) on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species and are listed on Appendix II of the Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES) (IUCN Red List, 2017).

The positive effects of photobiomodulation (PBM) therapy (formerly low-level laser therapy) were originally observed in a rodent model over 50 yr ago by Dr. Endre Mester, when he noted the effects that application of light had on hair growth and wound healing (Mester *et al*., 1968). PBM is a photochemical interaction that occurs between target cells and applied laser light. Mitochondria within cells contain chromophores that absorb photons from PBM. The primary chromophore of interest, the enzyme cytochrome c oxidase, is located in the mitochondrial membrane and impacts the activity of various molecules such as nitric oxide (NO), calcium ions, adenosine triphosphate (ATP), beneficial reactive oxygen species (ROS), and other signaling molecules (Freitas and

Hamblin, 2016). These molecules work together by various pathways to normalize metabolism and regulate proteins that are affected by redox reactions and involved in cellular proliferation and differentiation. Together with cytokines and growth factors, they aid in tissue recovery, repair, and the reduction of oxidative stress and inflammation.

In addition to the effects mediated primarily via the biologically active chromophore previously described, light-sensitive ion channels are also found within the cell membrane. These ion channels are gated by light and include transient receptor potential (TRP) channels that are activated by specific factors such as heat or cold, noxious chemicals, mechanical forces, voltage, and other mechanisms. When activated, TRP channels open, allowing ions such as sodium to flow into the cell. This results in an action potential that is realized as a nerve impulse. Mounting evidence suggests that light-mediated activation of TRP is responsible for some of PBM's mechanisms of action, including histamine-dependent wound healing effects and antinociceptive effects (Freitas and Hamblin, 2016).

The benefits of PBM in wound healing are well described in the literature. *In vivo* and *in vitro* studies have shown that PBM reduces pain, positively influences all phases of wound healing, and increases wound tensile strength via acceleration of the activity of fibroblasts, collagen synthesis, and neovascularization, thereby decreasing inflammatory cells and increasing the amount of elastic fibers in the wound healing process (Stadler *et al*., 2001; Medrado *et al*., 2003; Gal *et al*., 2006, 2008; Melo *et al*., 2011; Loreti *et al*., 2015; Wardlaw *et al*., 2019). It may also have potential benefits for infected wounds, possibly enhancing macrophage function and modulating the immune response (Burger *et al*., 2015) as well as potentially having some direct effects on microorganisms (Nussbaum *et al*., 2003).

Previous studies have also looked at the use of PBM in reptiles to treat surgically created incisional wounds (Cole *et al*., 2015; Cusack *et al*., 2017) and have found varying results, depending on the dosage used. In chelonians, other research has explored its use in superficial and deep traumatic wounds (Pelizzone *et al*., 2014), exposed organs following carapacial fractures (Nardini and Bielli, 2011), and in deep dermal ulceration in a softshelled turtle (Kraut *et al*., 2013). Findings in these studies included subjective improvement(s) in quality and/or rate of healing in PBM-treated lesions (Kraut *et al*., 2013; Pelizzone *et al*., 2014). For deeper wounds, including infected or ulcerated wounds in chelonians, a fluence of 4–6 J/cm^2 has been previously recommended (Mayer and Ness, 2017).

Case Report

A 7.1 kg adult, wild-caught, intact female Aubry's flapshell turtle, that had been housed in the collection for 21 months, was evaluated at Turtle Island (Graz, Austria) for rapid onset of multifocal, tan-white, 1.5 cm and smaller, crateriform, ulcerated lesions on the carapace and plastron. She had been housed with a single conspecific (smaller male Aubry's flapshell turtle) for 19 months. On Sept. 23, 2018 (17 days prior to identifying the ulcerative lesions), the patient and the smaller male were moved from a 600-L glass aquarium with a water depth of 34–38 cm, temperature range between 27°–29°C (81°–84°F), and constant water filtration (Eheim Professional 3, Deizisau, Germany) to a 3,040-L opaque enclosure with the same water source and water temperature at a depth of 30–35 cm. The turtles' diet consisted of frozen and thawed common rudd (*Scardinius erythrophthalmus*), European smelt (*Osmerus eperlanus*), Raitt's sand eel (*Ammodytes marinus*), big-scale sand smelt (*Atherina boyeri*), and live European carp (*Cyprinus carpio*) (when available), with three weekly feedings of three to five fish offered per feeding. Both turtles were examined during the transfer between enclosures and were clinically normal prior to introduction into the larger enclosure, which was shared with several smaller aquatic West African mud turtles (*Pelusios castaneus*) and East African black mud turtles (*Pelusios subniger*). The new enclosure contained the same hiding structures that had been present in the previous enclosure.

Seventeen days after the softshell turtles were moved to the new enclosure, the male specimen was observed out of the water, partially buried in the sand. Since this behavior can be a sign of stress in softshell turtles, both Aubry's flapshell turtles were examined. The male specimen had multifocal areas of erythema on the plastron and a few, 0.5 cm or smaller, tan-white, crateriform ulcers on the carapace. The female specimen had more than 10, tan-white, 1.5 cm and smaller, crateriform, ulcerated foci on the carapace and plastron; however, no erythema was visible on the female. No changes were observed in the level of activity, attitude, or appetite of either turtle and both were returned to their original enclosure, where they had thrived for the previous 19 months. After returning both turtles to their original enclosure, the erythematous and crateriform lesions on the male specimen resolved within 3 wk without medical treatment. During the same 3 wk period, the ulcerated lesions on the female specimen more than doubled in size, progressing to a severe ulcerative dermatitis that required medical intervention.

Logistical constraints necessitated that empirical treatment be started before advanced diagnostics could be performed. Empirical antibiotic therapy was initiated on 10 October 2018 with ceftazadime (Ceftazadim-MIP, 100 mg/ml, MIP Pharma GmbH, Blieskastel, Germany) at 20 mg/kg SC every 72 h, in the cranial half of the body adjacent to the forelimbs (Vogelnest, 2017). Lesions were debrided and flushed with 10% povidone iodine solution every 72 h (Betaisodona, 10 g/100 ml, Mundipharma Ges.m.b.H., Vienna, Austria). No improvement was noted after five doses, and ceftazidime was discontinued on 22 October 2018; however, topical debridement and flushing with 10% povidone iodine solution were continued every 72 h.

No improvement in ulcerative dermal lesions was observed over the next 15 days and the patient was started

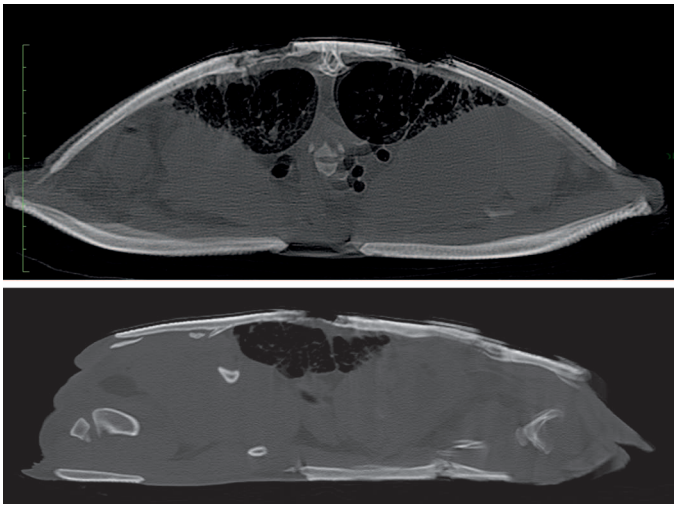

Figure 1. Sagittal and transverse computed tomography (CT) images of penetrating lesions and bone lysis in an Aubry's flapshell turtle (*Cycloderma aubryi*) 11 weeks after initial presentation.

on marbofloxacin (Marbocyl, 2%, Vetoquinol, Lure Cedex, France) at 5 mg/kg SC every 24 h, beginning on 7 November 2018. Lesions continued to be debrided and flushed with 10% povidone iodine every 48–72 h. Beginning on 15 November 2018, PanazymCreme (Veyx Pharma GmBh, Schwarzenborn, Germany) was applied to lesions after each debridement and povidone iodine flush. A slight decrease in the amount of necrotic and fibrinous tissue was noted; however, after 13 days, no change in lesion size was observed. Thus, the marbofloxacin and Panazym Creme were discontinued.

On 19 November 2018, a course of doxycycline (Vibravenoes, 20 mg/ml, Pfizer Corporation, Austria Ges.m.b.H., Vienna, Austria) was initiated at 30 mg/kg SC for the first dose, followed by 25 mg/kg SC every 72 h. Lesion debridement and sterile saline flushes of the lesions were continued every 48–72 h. After 21 days on doxycycline (eight doses), the ulcerative lesions had increased in size, and the patient had developed new lesions on both the carapace and plastron. Doxycycline was discontinued on 10 December 2018, and the patient was started on concurrent regimens of ceftazidime at 20 mg/kg SC every 72 h (received nine doses) and marbofloxacin at 5 mg/kg SC every 24 h (received 14 doses).

Debridement of the lesions on 27 December 2018 revealed progressive expansion of the necrotic margins. A computed tomography (CT) study was scheduled for the following day. The CT scan revealed multifocal osteomyelitis with extensive infiltration into the soft tissue and osteological structures of the carapace and plastron (Fig. 1). At least three lesions penetrated the full thickness of the shell, indicating a need for thorough surgical debridement.

On 29 December 2018, anesthesia was induced and maintained using 7 mg/kg ketamine (Ketamidor, 100 mg/ml IM, Richter Pharma AG, Wels, Austria) and 0.07 mg/kg medetomidine (Sedator, 1 mg/ml IM, Dechra Veterinary Products GmbH, Aulendorf, Germany). Meloxicam (Meloxidolor, 5 mg/ml, Le Vet Beheer B.V., Oudewater, Netherlands) at 0.15 mg/kg IM and sterile saline (0.9% NaCl, B. Braun Melsungen AG, Melsungen, Germany) at 20 ml/kg SC were administered during surgery for pain management and fluid support, respectively. All large lesions on the carapace and plastron were removed with 1-cm margins using an Aesculap Elan-E 2 bone saw (Aesculap AG, Tuttlingen, Germany) and a Dremel tool (Robert Bosch GmbH, Gerlingen, Germany) (Fig. 2). Debridement of the lesion on the left cranial carapace opened the coelom; therefore, the coelomic membrane was closed with 3.0 polydioxanone (PDS, Ethicon, Bridgewater, New Jersey, USA) using a cruciate suture pattern. Standard surgical excision was used to completely remove smaller lesions until normal tissue was visible. All debrided lesions were flushed with a total of 1.5 L of sterile saline and Cyprinocur powder (tyrothricin 0.5%, clotrimazole 2%, Sophien-Arzneimittel GmBh, Koblenz, Germany) was applied to all lesions on the carapace and plastron. At the end of surgery, 0.28 mg/kg of atipamazole (Atipam, 5 mg/ml, Dechra Veterinary Products GmbH) was given SC to reverse the mededomidine.

The patient was dry-docked for 6 days after surgery. Postsurgical hemorrhage from a large lesion on the right caudal carapace and multiple lesions on the plastron were addressed by placing 5 cm × 5-cm gauze pads under moderate pressure. Gauze pads were checked and replaced as needed with dilute povidone-iodine-soaked gauze packing, and Cyprinocur powder was also applied to the left caudal lesion on the carapace. Gauze pads remained in place until 4 January 2019, when they could be removed without hemorrhage occurring.

Microbial samples, including a culture swab and 3–5-mm tissue samples which included bone fragments, were collected from lesions on the carapace and plastron during the surgical procedure. All samples were submitted to IDEXX Laboratories (IDEXX Vet Med Labor GmbH, Boersegasse 12/1, A-1010 Vienna, Austria) under test code PK2 for aerobic culture and antibiotic sensitivity testing. The bacteria were cultivated in aerobic culture mediums (tryptone soya agar [TSA] blood agar, MacConkey agar, and Hematin agar) and identified using matrix-assisted, laser desorption ionization-time of flight mass spectrometry (MALDI-TOF MS) (B. Altherr, DVM, IDEXX Laboratories, personal communication, 2022). *Stenotrophomonas maltophilia* and *Achromobacter* (*Alcaligenes*) *xylosoxidans* were isolated from the samples submitted. *Stenotrophomonas maltophilia* was identified by the laboratory as a likely environmental contaminant, and the laboratory reported that they were unable to perform sensitivity testing on the *S. maltophilia*. *Achromobacter xylosoxidans* was sensitive to trimethoprim/sulfamethoxazole, imipenem, and meropenem but resistant to ceftazidime, marbofloxacin, and doxycycline. Marbofloxacin was discontinued at the time of surgery; ceftazidime was discontinued based upon the results of the culture and sensitivity results. No antibiotics were administered after ceftazidime was discontinued.

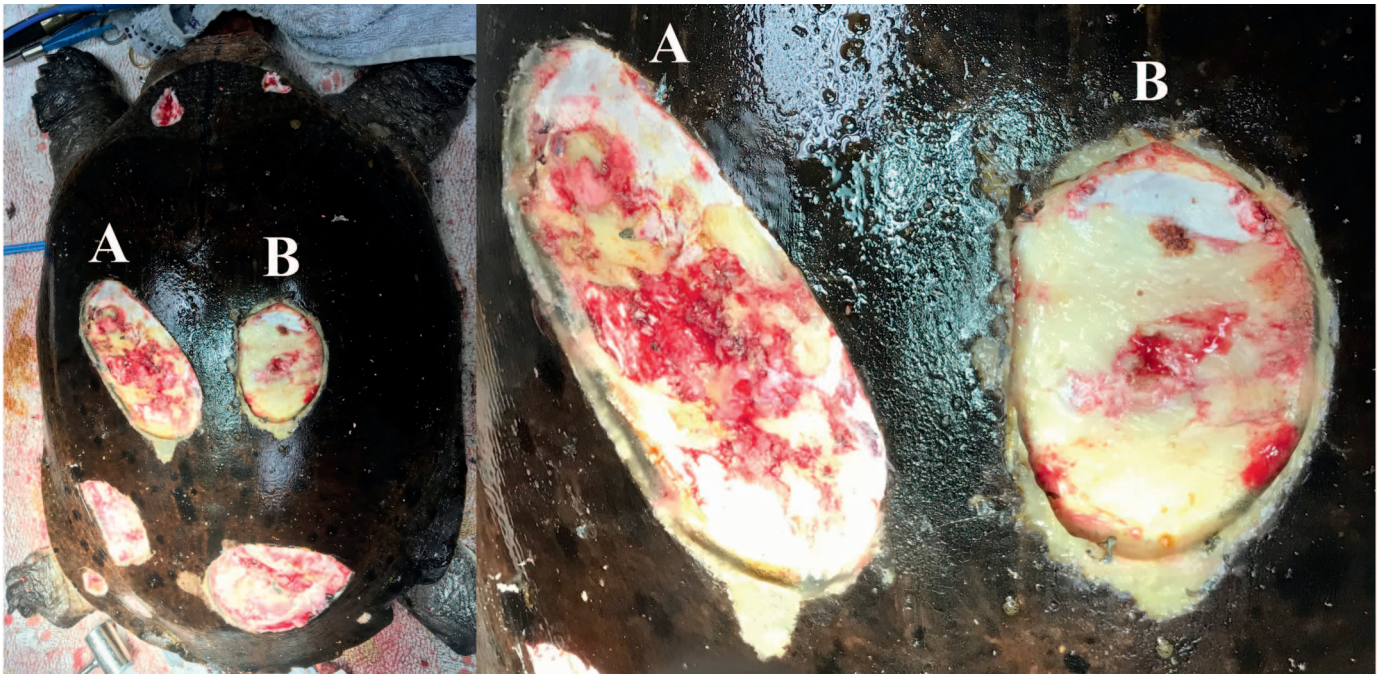

Figure 2. Carapace lesions in an Aubry's flapshell turtle (*Cycloderma aubryi*) immediately following surgical debridement. (A) The large cranial lesion on the left and (B) the large cranial lesion on the right were used to compare the effects of photobiomodulation (PBM) treatment over the following 2 months.

The patient refused to feed voluntarily while dry-docked. She was only offered the thawed frozen fish component of her normal diet, so based on recommendations from Dr. Markus Baur (M. Baur, DVM, Auffangstation fuer Reptilien, personal communication, 2019), she was supplemented with SC administration of glucose-spiked sterile saline solution (8 parts 0.9% NaCl, 2 parts G-5, 50 mg/ml) at 1% (10 ml/kg) of body weight/day until she began feeding regularly, which only occurred when in water. Prior to reintroducing the patient into her enclosure, a JBL Procrystal UV-C Compact Plus 18 W Water Clarifier (JBL GmBh & Co. KG, Neuhofen, Germany) was added to the water treatment system. Beginning on 4 January 2019, the patient was placed in water in her normal enclosure for 1 h/day to support hydration and encourage feeding. Shell lesions were flushed with sterile saline and Cyprinocur quick powder was applied to the larger lesions before the turtle was placed in water.

A recheck examination on 26 February 2019 revealed that the large lesions on the carapace and plastron had not decreased in size since the surgery, and visible signs of progressive healing, such as active granulation tissue and/or decrease in size or depth, were slow. It should be noted that the lesions also had not advanced or worsened since the surgery date. Based on the case status, it was decided to incorporate PBM therapy (model CTL-10 Therapy Laser; Companion Animal Health, New Castle, DE, USA). To more effectively evaluate the response to treatment, PBM was only initiated on two of the four large lesions on the carapace (the cranial left and caudal right lesions); however, all lesions on the plastron were treated. Treated and untreated lesions were measured and photographed prior to initiating PBM therapy. Lesions were measured at the points of maximum length and width, either from the edge of the bone, or in cases that did not involve bone, as close as possible to the initial incision line. All lesions were measured and photographed before each PBM session. Measurements were not taken after PBM therapy was initiated, as the lesions appeared to heal via an increase in granulation tissue within the lesions, which progressed toward the lesion margins; the circumference of the lesions did not decrease markedly.

On 26 February 2019 (day 137 of treatment, day 0 of PBM), PBM utilizing 980 nm wavelength light was initiated using a small, non-contact treatment head (spot size = 1.54 cm^2 at aperture exit) held 2.5 cm from the treatment surface at a radiant power setting of 2 W (irradiance at lesion surface was approximately 1.3 W/cm^2). A fluence (energy density) range of 6–12 J/cm^2 was delivered depending on the size of the lesion. The treatment area and fluence range calculations included a 2–3-cm margin of normal tissue around the lesion, and treatment was applied off-contact in a continuously moving grid pattern at a speed of 2.5–7.5 cm/sec according to the manufacturer's recommendations. Treatments were administered 3 days and 6 days after starting PBM. At this juncture, Dr. John Godbold (J. Godbold, DVM, Stonehaven Veterinary Consulting, personal communication, 2019) was consulted, and a new protocol was established based on his recommendations. Every 3 days thereafter, an increased fluence of 15–22 J/cm^2 was applied, depending on the size of the lesion, with all other parameters remaining unchanged. Note that a 1-cm margin was treated on the medial aspect of the lesion on the

left cranial carapace in order to avoid direct treatment of the lesion on the right cranial carapace.

On 13 March 2019, after receiving a total of four PBM treatments over a 17 day period, visible improvement was noted in the PBM-treated lesions. Improvements included increased vascularization and improved color in the soft tissue, and the central regions of the crateriform lesions appeared to be filling in with granulation tissue, approaching the same height of the normal shell at the margins of the lesions. Appreciably greater improvements were observed in the PBM-treated lesions than in lesions which had not been treated with PBM. Based on the history of prolonged wound healing in this patient and the observed response to therapy, it was determined that it would be in the best interest of the patient to treat all lesions with PBM from that point forward. At the end of the PBM treatment cycle, the lesions on the carapace and plastron, which had been treated from the beginning, received a total of nine treatments; the two lesions on the carapace, which had not been treated initially (cranial right and caudal left), received a total of five PBM treatments. PBM therapy was discontinued on 25 March 2019 (Fig. 3).

By August 2019, the patient had made a full recovery; all shell lesions appeared to be fully healed, with a complete outer tissue layer that was firm to the touch in locations where it covered osteological shell structures, although significant depigmentation was present at the sites of larger lesions. As of June 2022, the patient weighed 10.4 kg, representing a 3.3-kg weight gain (an almost 50% increase in body weight) since presenting in 2018 with ulcerative dermatitis. To date, there has been no recurrence of dermatological disease and this patient appears to be healthy and robust (Fig. 4). On 3 August 2021, approximately two and a half years postsurgery, a follow-up CT showed partial bone regrowth at surgical resection sites on the carapace and plastron, with no indications of infectious disease detected (Fig. 5). This specimen went on to lay two clutches of eggs; her first clutch was the first ever successful hatching of this rare turtle species under human care.

Discussion

Severe ulcerative dermatitis and osteomyelitis were diagnosed and successfully treated in this Aubry's flapshell turtle. Infectious dermatologic disease, and specifically ulcerative dermatitis or "shell rot," is a common presenting complaint in aquatic and terrestrial chelonians that is often associated with bacterial septicemia, although it may have bacterial, fungal, and/or viral etiologies (Jacobson *et al*., 1980; Hongda and Lihua, 1996; Rosskopf and Shindo, 2003; Hoppmann and Barron, 2007; Johnston, 2008; Hatt, 2010; Sakaguchi *et al*., 2011; Chen *et al*., 2013; Palmiero and Roberts, 2013; Vogelnest, 2017; Woodburn *et al*., 2019). Multifocal ulcerative dermatitis in chelonians, especially those maintained under human care, has historically been associated with septicemia and considered a sequela of underlying husbandry or management practices, while single or focal lesions are more commonly attributed to traumatic injury. Severe ulcerative dermatitis can be challenging to treat, even with appropriate antimicrobial therapy and modifications to husbandry practices (Rosskopf and Shindo, 2003; Hoppmann and Barron, 2007; Johnston, 2008; Hatt, 2010; Palmiero and Roberts, 2013; Vogelnest, 2017). Chronic lesions may exhibit delayed or slow healing and persist for months or years before full recovery is made and/or treatment failure is marked by the death of the patient. Multiple modalities have been utilized for wound treatment of exotic animals, including negative pressure wound therapy, electrical stimulation therapy, therapeutic ultrasonography, hyperbaric oxygen therapy, skin expanders, xenographic skin grafts, porcine-derived biomaterials, and *in vivo* bioreactors (Divers, 2000; Foerster, 2000; Altomare *et al*. 2009; Stanley, 2017; González and Mayer, 2019). PBM was utilized in this case because it was readily available and could be administered with minimal handling and stress to the patient (no sedation or restraint was required, and treatment duration was roughly 5 min). Additionally, there is a growing body of empirical and published evidence that PBM is effective in supporting wound healing in chelonians.

In the case of this Aubry's flapshell turtle, shortly before the patient developed early signs of dermatologic disease, she had been moved into a larger enclosure in an effort to improve on husbandry practices under which she had been thriving. While the water source, approximate depth, temperature, hiding structures, and diet remained functionally unchanged, the new enclosure was roughly five times larger than the original enclosure and contained multiple smaller aquatic turtle species (in addition to the male conspecific with whom the patient had previously been housed). While the exact etiology and pathogenesis of the multifocal ulcerative dermatitis in this case remain unknown, the authors suspect a combination of stress associated with the move to a larger, multispecies enclosure and a novel microbial community present therein, which likely played a significant role in the pathogenesis of this patient's infectious disease. Multiple antibiotics were administered without symptom resolution. Some possible explanations include incorrect antibiotic choice, antimicrobial resistance, inadequate dosing, inadequate blood levels, inadequate antibiotic penetration to the target site, a non-bacterial etiology, or secondary bacteria. Because neither a fungal culture nor histopathology were performed, it is not possible to determine the role that bacteria or other pathogens may have played in the disease process of this case. Histopathogy, bacterial culture, and fungal culture earlier in the disease progression may have allowed for earlier diagnoses or a more guided antimicrobial selection, which could have yielded earlier symptom resolution. Ideally, culture and sensitivity testing should be used to guide antibiotic treatment, following the principles of good antibiotic stewardship (Hedley *et al*., 2021).

For aquatic turtles, such as the softshell and flapshell species, chronic or non-healing lesions pose an additional degree of difficulty during lengthy treatment regimens. The

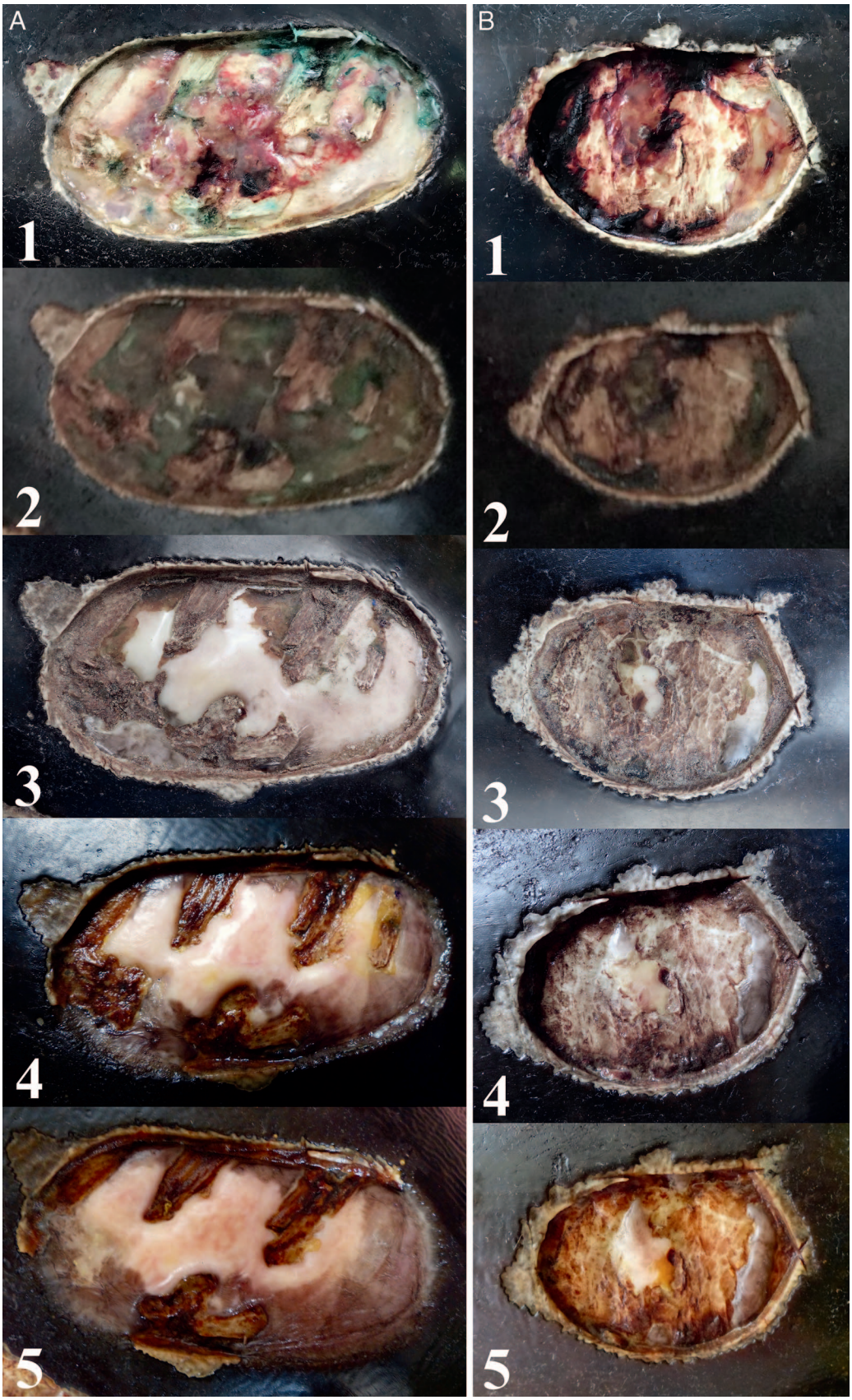

Figure 3. Carapace lesions in an Aubry's flapshell turtle (*Cycloderma aubryi*) documenting changes over time in two lesions. (A) Lesion treated with photobiomodulation (PBM) therapy beginning on 26 February 2019, (B) lesion originally not treated with PBM. This lesion was treated with PBM beginning on 13 March 2019 (1) 4 January 2019, 1 wk postsurgery; (2) 21 January 2019, 24 days postsurgery; (3) 26 February 2019, 60 days postsurgery, and immediately before initiating treatment of lesion A with PBM; (4) 13 March 2019, 75 days postsurgery, at which point lesion A had received four PBM treatments and lesion B had not been treated with PBM; (5) 25 March 2019, 87 days postsurgery, lesion A had received nine PBM treatments and lesion B five PBM treatments.

Figure 4. Carapace lesions in an Aubry's flapshell turtle (*Cycloderma aubryi*) on 1 July 2022, more than 2 yr after ending treatment. Image on right shows a close-up of the same lesions.

stress associated with treatment and handling, such as behavioral changes associated with prolonged dry docking, can offset and, in some cases, may outweigh potential benefits provided by therapeutic and treatment efforts. At the same time, normal environmental biota in even the most carefully managed aquatic systems can act as secondary invaders, posing an ongoing contamination threat in unhealed wounds. Thus, therapeutic modalities that support or enhance wound healing and allow patients to be returned more quickly to optimal husbandry conditions may play an important role in achieving successful outcomes in aquatic turtle species.

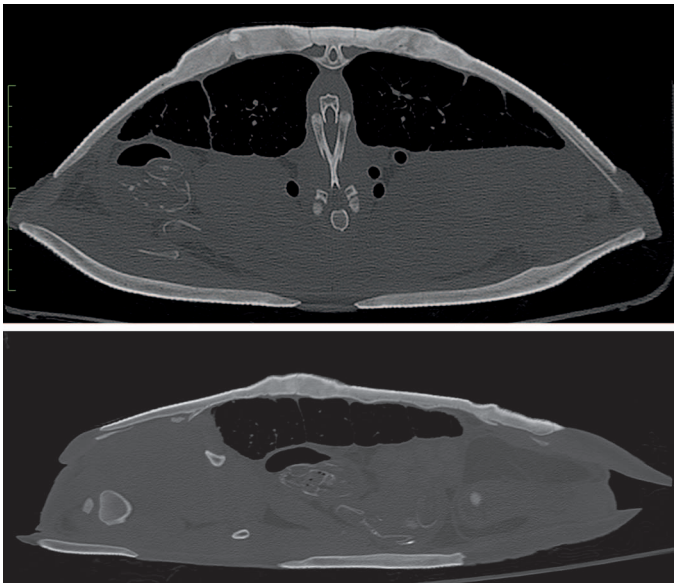

Figure 5. Sagittal and transverse CT images of the same penetrating lesions in an Aubry's flapshell turtle (*Cycloderma aubryi*) shown in Figure 1, from followup CT on 4 August 2021, 29 months after ending treatment, showing healed shell lesions with bone regrowth.

Other research on the use of PBM in regard to healing rates in reptiles, including chelonians, has been published. Findings in some of these studies included subjective improvement(s) in quality and/or rate of healing in PBM-treated lesions (Kraut *et al*., 2013; Pelizzone *et al*., 2014; Cole *et al*., 2015), even though other studies did not report significant differences in PBM-treated incisions and controls. The authors of one such study (Cole *et al*., 2015) theorized that a dose of 5 J/cm^2 may have been insufficient due to greater reflection or absorption by reptilian scales. A recent study in iguanas noted that wounds treated with PBM at 10 J/cm^2 were significantly smaller at 14 days compared to those treated with topical ointment (Cusack *et al*., 2017). Other literature suggests that chronic or infected wounds and thermal burns may require a more aggressive treatment schedule or higher fluences (energy densities [J/cm^2]) in order to achieve beneficial results (Bradley, 2017).

The patient in this case report was treated with a fluence consistent with higher dose recommendations. Although softshell turtles lack hard scutes or scales to reflect or absorb light, PBM doses at the higher end of reported ranges was elected based on recommendations from colleagues with extensive experience treating reptiles with PBM and the reported literature. The authors recognize the limitations of a single patient case report, which make it impossible to definitively determine if the higher fluence ranges used for this patient were responsible for the perceived difference in healing as compared to some of the literature where no significant difference in healing was reported; however, the possibility of dose dependence cannot be ruled out. It should be noted that distant wound healing has been documented with PBM (Rodrigo *et al*., 2009). Thus, the proximity of lesions on this patient

presents an additional confounding factor when comparing healing of treated *vs.* untreated lesions in this single-patient case report.

Lafortune *et al*. (2005) stated that reported healing times for shell damage have been variable, ranging between 3 months (Rosskopf and Woerpel, 1981), 6–30 months (Mitchell and Diaz-Figueroa, 2004), and up to 1–2 yr (McArthur and Hernandez-Divers, 2004). These healing times were reported with terrestrial or hard-shelled aquatic chelonians. Softshelled turtles significantly differ anatomically from all other chelonians and therefore may have different healing times or responses to specific therapies, such as PBM.

In this case, PBM therapy was initiated nearly 5 months into treatment, and 2 months had passed since surgical debridement. The large lesions on the shell had shown minimal, grossly observable signs of healing progress in over a month. It is noteworthy that the lesions treated with PBM showed visual signs of healing after only a few treatments, while the two untreated lesions did not show visible signs of healing. Moreover, after treating the previously untreated "control" lesions with PBM, they too began to show visible signs of healing after only a few treatments. It is the clinical impression of the primary author that signs of healing observed after initiating PBM therapy marked a turning point in this case, as the shell lesions had remained functionally static in size and depth prior to that point.

Aubry's flapshell turtles are listed as Vulnerable by the IUCN, with habitat degradation and exploitation for local consumption identified as major threats. The range-wide decline of this species is anticipated to exceed 30% based on past declines and anticipated continuing and/or intensifying exploitation, and have an estimated generation time of 20 yr (IUCN Red List, 2017). It is important to continue to investigate medical modalities that enhance our ability to meet the health and welfare of patients and collection animals, especially with species of conservation concern. PBM can be a valuable therapeutic tool that should be considered for treating ulcerative dermatitis in softshell turtles, especially in patients with delayed wound healing or chronic dermatologic lesions, and it is a therapeutic modality that warrants continued research and evaluation for use with exotic species.

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Conflict of Interest: Author Lisa Miller is currently employed by LiteCure/Companion Animal Health and was involved with article preparation. All authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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